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LANDSAT DEMONSTRATION 826-4873

School of Natural Resources
Office of the Dean

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NASA AMES RESEARCH CENTER

THE APPLICATION OF REMOTE SENSING TECHNOLOGY IN NORTHERN CALIFORNIA

by

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INTRODUCTION

The primary objective of this project is to determine optimum techniques for training and consulting with potential users of Landsat digital technology. The four specific goals stated in the project proposal have been addressed during the first six months of operation. Activities directed toward these goals are discussed individually in this report and documented results are included as Appendices.

DEVELOPING CURRICULA

Remote sening curricula are being developed to assist in the training of potential users of Landsat Data. Training modules are being prepared which may be used by an individual in a self-paced learning environment, or given to a group in a classroom. These will include a text and an accompanying set of 35mm slides.

The first module addressing the use of computer systems to process Landsat data is 85% completed. It is composed of a lecture presentation covering statistical methods for clustering and for maximum likelihood classification and a laboratory exercise using a mini-computer system(Appendix 1).

A second module describing techniques for evaluating the accuracy of Landsat classifications using cluster sampling and aerial photography is 30% completed. Several formative discussions have taken place with Don Card(NASA Ames) to define this module. An evaluation of a Landsat classification has been completed. The instructional text needs to be written and integrated into the example evaluation.

Sampling theory for natural resources inventory is being assembled into another module and is now 10% complete. Discussions with Don Card(NASA Ames) have revealed significant instructional barriers which must be addressed before completion. For example, how to teach sufficient statistical theory to enable students to understand complex multi-stage sampling schemes and not overwhelm them with information? We will continue to address these difficulties and to develop this module with Don Card's guidance.

LANDSAT DEMONSTRATION PROJECT

A final version of the technical plan and detailed task plan have been completed after review and discussion with the US Forest Service and NASA (Appendix 2). The task plan indicates goals completed as well as target dates for the future. The work is on schedule. The 1978 Landsat data has now been registered to USGS base maps to within 1.2 pixels (rms error). One hundred and forty training areas and the Ranger District boundaries have been digitized. Work is now underway to define a final statistics file for the 1978 data on 9 Compartments of the Ranger District.

Much of the digital analysis has been accomplished at the District Office in McCloud, California using a portable terminal to connect to computer systems at Ames. This "on-site" training has been key to the technology transfer process. Alice Forbes (Forest Technician assigned to the project) has been involved in every stage of digital analysis.

DEVELOPING TECHNICAL SCHEDULES AND CONSULTING TECHNIQUES

The task plan for the Landsat Demonstration Project with the US Forest Service (Appendix 2, p. 10) represents a synthesis of our experiences and frustrations encountered in keeping to a work schedule. The plan represents our estimate of a realistic schedule and set of goals for a one-year Landsat Demonstration Project. A brief final report will be prepared on scheduling, incorporating our experience as we complete our current demonstration.

Two information needs have been identified for consulting with potential users of Landsat digital data. The cost of using Landsat is always a concern to people unfamiliar with the system. To assist us in answering this question we have prepared a comprehensive cost summary of the US Fish and Wildlife Service Landsat Demonstration Project (completed under a previous grant, NSG-2244). Total cost of this detailed project was 21 cents per acre (Appendix 3).

The accuracy of a Landsat classification must also be determined to allow potential users to evaluate the effectiveness of Landsat-based inventories. Aerial photography was used, within a cluster sampling scheme, to evaluate the accuracy of the US Fish and Wildlife Service Landsat classification of vegetation cover, completed under NSG-2244. The classification was found to be 91% accurate (Appendix 4). These and other informational needs and consulting techniques will be incorporated into a final statement of our consulting philosophy.

Results of the cost analysis and accuracy evaluation will be documented in a paper accepted for publication in the proceedings of a sysmposium at the University of Idaho, "Remote Sensing of Natural Resources," September 10-14, 1979. The paper is titled:"Watershed Condition Mapping of the Hoopa Indian Reservation Utilizing Landsat Digital Data."

We have begun working with Professor Joseph Leeper, Geography, Humboldt State University, to train him for his sabatical leave with NASA Ames Research Center. Professor Leeper plans to complete a Landsat classification at Humboldt using the phone line connection to the computer systems at Ames. A Landsat data window has been defined and training areas are being selected for a Landsat classification of small urban areas. The direct experience gained working with Professor Leeper will assist us in understanding the needs of potential users of Landsat in several disciplines.

SUPPORT THE STATE-WIDE LANDSAT FORESTRY RESOURCE ASSESSMENT IN NORTHERN CALIFORNIA

A portion of a one-week California Department of Forestry training Course was developed, documented, and presented by personnel from this grant. The Course was given by NASA Ames, at Moffett Field, October 2-6, 1978. We presented similiar materials at a US Forest Service Training Workshop held at Ames from January 29 - February 2, 1979. Working closely with NASA training contractors and government personnel, we were able to integrate lecture material and a lab exercise on computer analysis into comprehensive workshops covering many aspects of remote sensing applications. Several examples of the materials used in these courses are included in Appendix 1.

In order for us to more effectively address the inventory needs in Northern California, we have begun to establish Landsat computer analysis capability at Humboldt State. An initial assessment of the computer processing environment at Humboldt indicates that the transfer of NASA software to Humboldt's mini-computer system is the most feasible alternative at this point. We will continue to work closely with NASA Ames Research Center to achieve this goal.

APPENDIX 1

LANDSAT DIGITAL ANALYSIS MODULE

DIGITAL ANALYSIS TRAINING MODULE

SUMMARY

- LECTURE 2 hrs.
    - Spectral space (histograms, two channel plots)
    - Information vs. spectral classes
    - Supervised classification
    - Unsupervised classification
    - Guided clustering
    - Computer systems

- COMPUTER EXERCISE 5 hrs.
    - ID resource information classes
    - Select training areas
    - Clip data windows from Landsat scene
    - Create histograms, determine No. of clusters
    - Cluster on each training window
    - Create statistics files
    - Merge and pool statistics files
    - Create final statistics
    - Classify - maximum likelihood
    - Evaluate classification using U-2 photos
    - Refine classification

- WORK BOOK
    - Lecture narrative with slide diagrams and imagery
    - Exercise instructions and workflow diagrams
    - Complete command structure for interactive computer systems

- PURPOSE
    - Understand the philosophy of computer assisted analysis
    - Build familiarity with computer systems
    - Prepare a user to process multispectral data on their own

Proposed Outline of

Digital Analysis Module

I. Lecture Presentation

This section to include a narrative and slide illustrations. The presentation could be given in a self-paced learning situation. This presentation will be segmented into blocks of knowledge represented by steps A-E below. Each of these segments will be presented as a learning station at Donna's International Training Course in August. As per Dale's suggestion, we are planning a round robin workshop at Donna's course with several stations. Explanations, handouts, and graphic displays to be at each station.

A. Philosophical Approach of Computer Processing

1. Spectral Space
   a. One dimension - the histogram
   b. Two dimensions - the "two channel map"
   c. N-Dimensions - hyperspace
2. Contrast to physical or image space, the philosophy of photo interpretation.

B. Information classes vs. spectral classes

C. Supervised classification - maximum likelihood

D. Unsupervised classification - clustering

E. Guided clustering

II. Laboratory Exercise

This section to include a written summary of instructions given participants in the exercise. Slide illustrations will accompany the material. The section to also include a written summary of the activities students take part in during an actual lab exercise. The EDITOR Software Package is used as an example of an interactive computer system.

A. Introduction to interactive computer systems.

B. Instructions for completing the exercise.

C. Summary of exercise activities.

1. Identify resource information classes
2. Select training areas
3. Cluster resource classes
4. Create statistics files
5. Pool and merge to final statistics
6. Classify
7. Evaluate and refine classification

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DIGITAL ANALYSIS OF MULTISPECTRAL SCANNER DATA

Lecture

by L. Fox

Objectives

After this presentation you should understand:

1. Philosophical differences, computer vs. image interpretation.
2. The concept of spectral space.
3. Difference between Information Class and Spectral Class.
4. Supervised classification.
5. Unsupervised classification.
6. Guided clustering.

Content Summary

Digital analysis is explained using three building blocks of understanding; spectral space, information classes and spectral classes. Spectral space is the mathematical space defined by Landsat spectral counts in several bands. Pixels representing a given type of land cover will tend to cluster in certain regions of spectral space.

The information class is an important concept as it defines a group of pixels representing one category which is meaningful to the people classifying the data. The information classes may be general (e.g. Forest Land) or quite specific (e.g., Deciduous Forest)

Spectral classes define pixels which have a similar spectral signature. They should represent one information class yet each information class may contain several spectral classes.

A comparative discussion of supervised and unsupervised classification follows with all statistical concepts explained graphically. Using the supervised approach, one seeks to define training areas for each information class desired. Statistics derived from training areas are used to drive a maximum liklihood classification.

The unsupervised technique is used to define a specified number of spectral classes throughout an entire region. Meaningful labels are later attached to these spectral classes.

Guided clustering allows the analyst to cluster within a training area. The process attempts to solve the problem of unwanted spectral variation

in the supervised strategy and unknown names of information categories in the unsupervised strategy.

Understanding Assumed

1. Landsat pixels compared to aerial photographs.
2. Image resolution, interrelation with spectral signature.
3. Landsat digital numbers or spectral counts.
4. Spectral signatures.

Outline of Content

I. Introduction

Computer processing philosophy compared to air-photo interpretation.

II. Spectral Space

A. Description and comparison to photo products.

1. One dimension, the "histogram."
   a) Means
   b) Variances
2. Two dimensions, the "two channel plot."
   a) Means
   b) Variances
   c) Covariances
3. Many dimensions, compare to reflectance curve.

III. Information Classes vs. Spectral Classes

A. Ideal Conditions

1. Every information class represented by one spectral class.
2. Every information class represented by more than one spectral class.

B. Unacceptable Conditions

1. Information classes not represented by any spectral class.
2. Spectral classes representing more than one information class.

IV. Computer Classification

A. General problem - Subdivide spectral space such that:

1. All spectral classes are separable.
2. All spectral classes represent one information class.

B. General Procedure

1. Define each spectral class (for every channel) by:
   a) Mean reflectance value.
   b) Variance (Std. dev.^{2})
   c) Covariance matrix - shows attitude of class.
2. Use the classes defined (called statistics) to classify the Landsat scene by:
   a) Maximum liklihood.
   b) Many other decision rules.

V. Supervised Classification

A. Approach

1. Select training areas - define information classes.
2. Create statistics files.
3. Maximum liklihood classification.
   a) Relate to histogram.
   b) Spectral confusion problems.
4. Evaluate results.
5. Iterate if accuracy is poor.

B. When used: resource information classes represented by one spectral class.

C. Problems:

1. Total spectral variation of information classes is unknown.
2. Several spectral classes may occur within one information class or training area. No way of knowing this.
3. General concept subdivides spectral space into information classes not spectral classes.

IV. Unsupervised Classification or Clustering

A. Approached

1. Select number of spectral classes desired.
2. Use clustering routine to establish spectral classes, a final stat file.
3. Determine the information class associated with each spectral class defined.

B. When used: resource information classes represented by several spectral classes.

C. Problems

1. Limits on the number of pixels clustered at one time.
2. Pixels containing two or more information classes are sampled which may distort statistics.

3. Limited control of what classes are created.
4. Concept results in a stat file based on spectral information only. No concern for what the analyst may want out of the data.

VII. Guided Clustering

A. Approach

1. Select training areas - generally define information classes.
2. Create histograms of each training area for every channel.
3. Determine the number of spectral classes present in the information class by clustering.
4. Repeat steps 1-3 for every general information class.
5. Combine all classes.
6. Pool similar classes or delete classes as necessary to create stat file.
7. Maximum liklihood classification.

B. Advantages

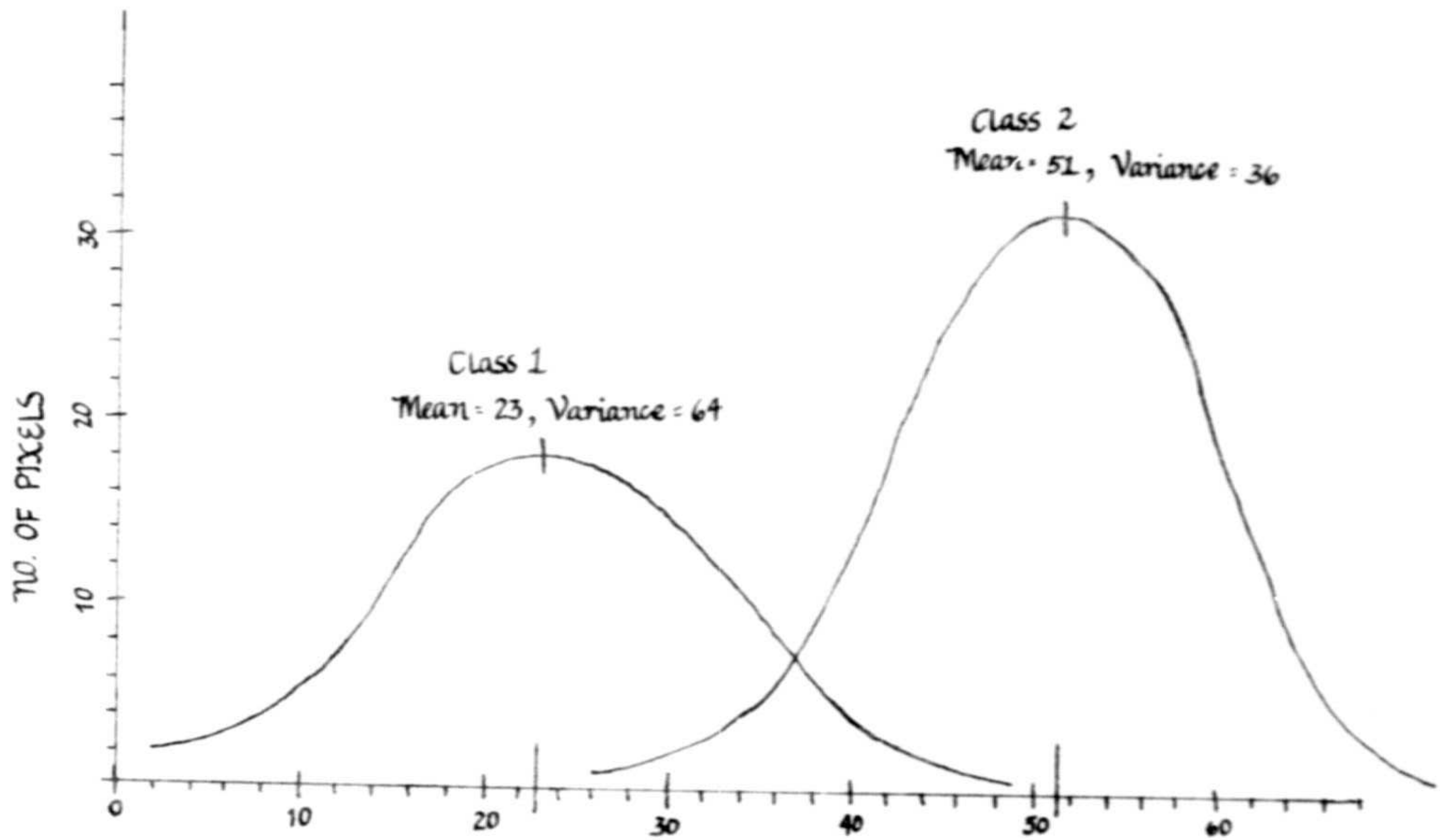
1. Control over the clustering process as a limited number of spectral classes are requested within a training area.
2. Pixels containing many information classes are relegated to a separate class which can be deleted.
3. Clustering finds spectral variation within information classes.
4. Possible to concentrate on separating information classes which are similar spectrally.

C. Problems

1. Spectral classes not occuring in training fields are not considered, causing missclassification.
2. Difficult to establish training areas containing enough pixels (several spectral classes per training area).

Viewgraph 1

LANDSAT HISTOGRAM



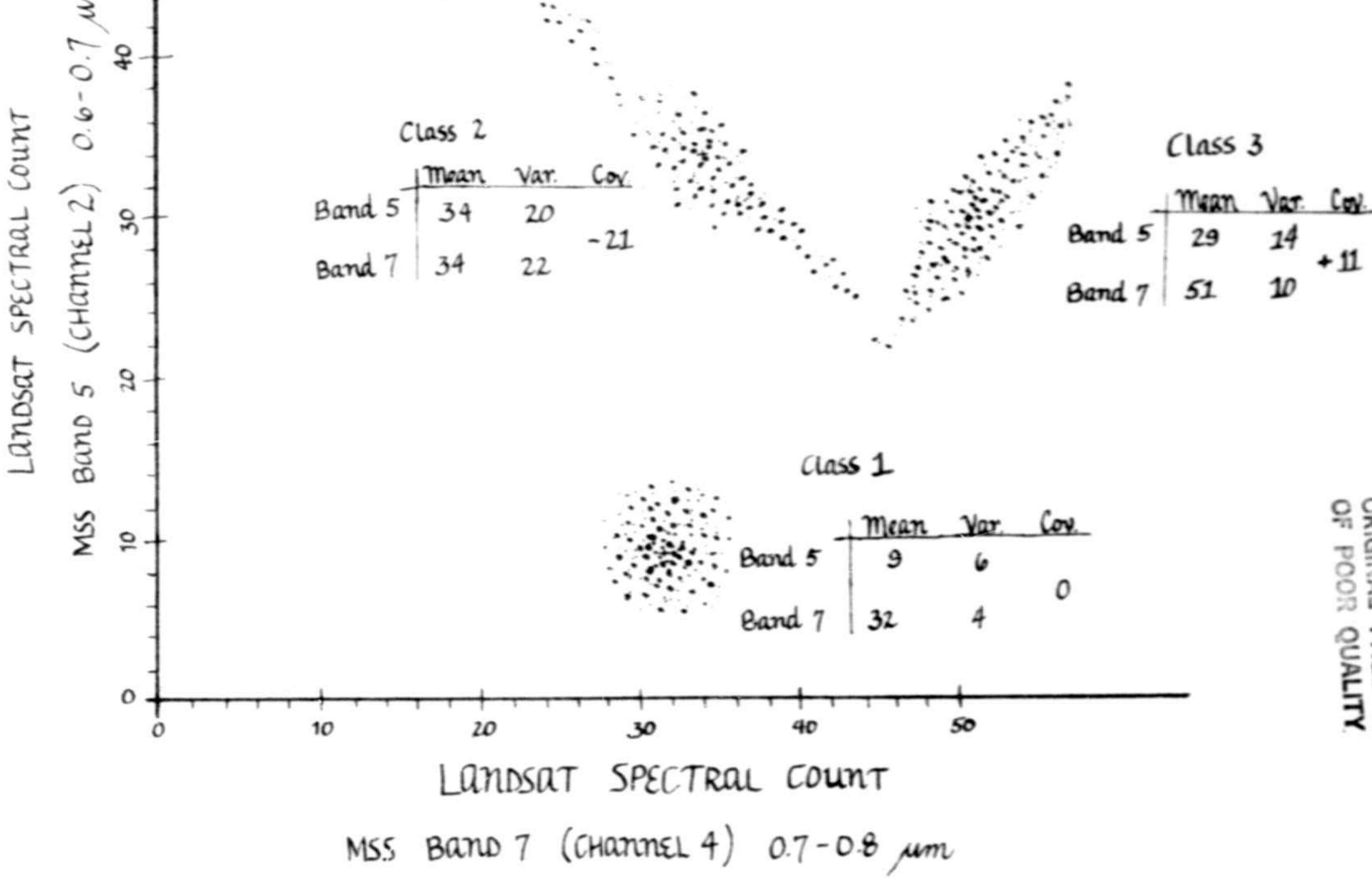
LANDSAT SPECTRAL COUNT

MSS BAND 7 (CHANNEL 4) 0.8 - 1.1 μm

Viewgraph 2

TWO CHANNEL MAP

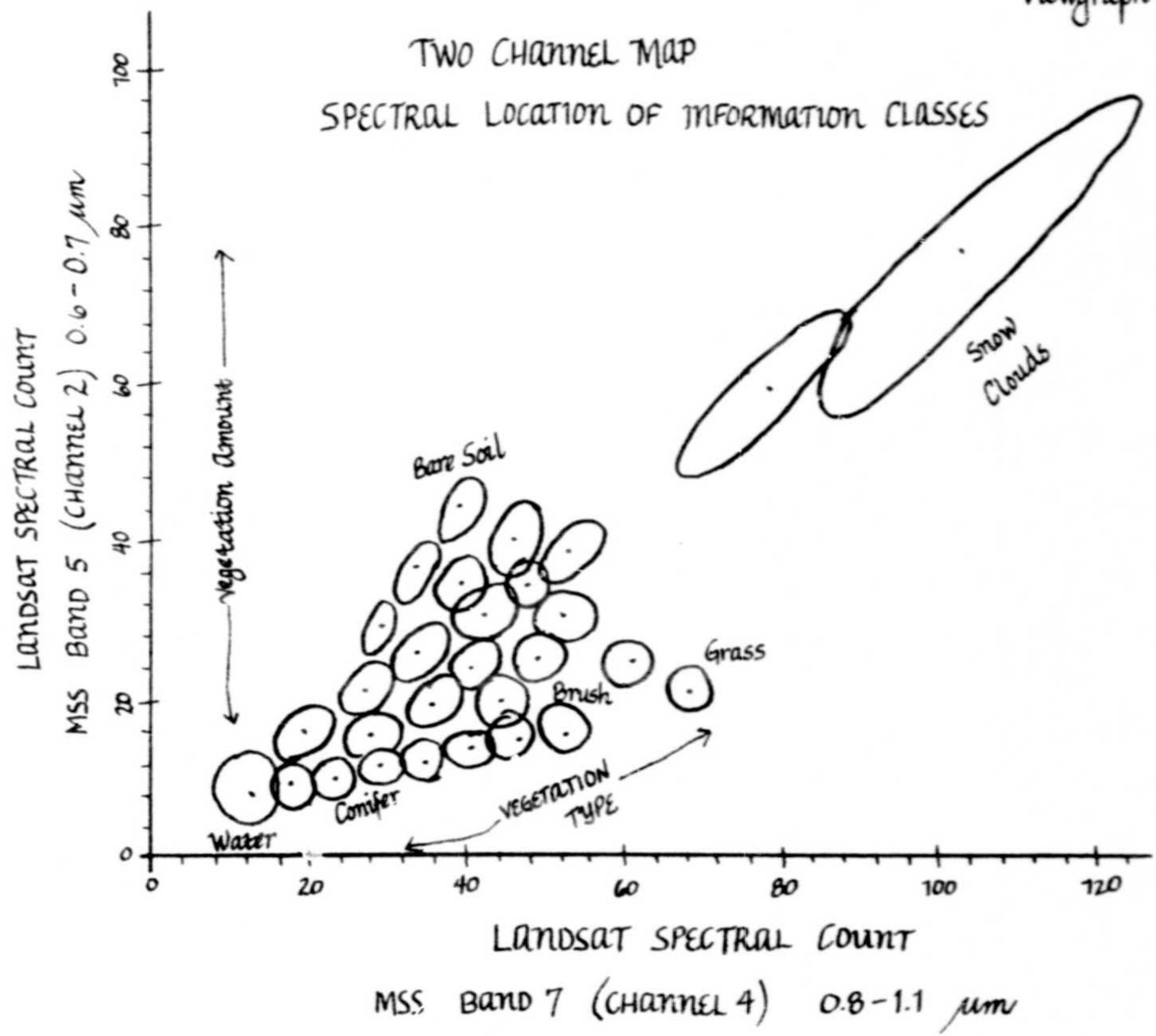
DESCRIBING SPECTRAL CATEGORIES



Viewgraph 3

TWO CHANNEL MAP

SPECTRAL LOCATION OF INFORMATION CLASSES



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INTERACTIVE COMPUTER SYSTEMS FOR DIGITAL ANALYSIS

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Lecture

by L. Fox

Objectives

After this presentation you should understand:

1. Philosophy of interactive processing.
2. Basic componets of systems design.
3. The multi-level program concept.

Content Summary

An introduction to interactive, multi-level computer processing will be given. Interactive processing allows the user to communicate with the computer during the processing sequence. The concluding analysis steps can be altered as the results of early processing beoome known. This flexibility is not a characteristic of batch processing.

The basic components of an interactive mini-computer system designed to process Landsat data include: a central processor, control terminal and a color television display. The processor performs the logic functions as per instructions given through the control terminal. The color display allows one to see how the classification will look when color coded and make changes as necessary.

The multi-level concept is fundamental to most computer systems processing Landsat data. The computer programs are arranged in a hierarchical fashion to allow for a logical flow of work within the system.

Understanding Assumed

No specific computer knowledge required.

Outline of Content

I. Introduction - Philospoply of interactive computers.

   A. Batch processing.
   B. Interactive processing.

II. System Components

A. Control terminal.

B. Color CRT/Output terminal.
   1. Enhance data.
   2. Color code the classification.

C. Central processor.

D. Memory.

III. Work Flow

A. Among system components.

B. Within a multi-level framework.

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OUTLINE OF COMPUTER LABORATORY SESSION

Processing Sequence - Landsat Digital Analysis by Ken Mayer

EDITOR Software - Guided Clustering (supervised)

1. Identify resource categories - Delineate on photo's, maps (7½ min.) and line printer maps.
2. Select training areas on line printer map and record row and column coordinates. Each person choose one resource category and select 3 - 4 training windows. Each training window must be at least 25 pixels.
3. Clip windows.
4. Create histograms for the training windows and determine the number of clusters.
5. Cluster each training window.
6. Create statistics files.
7. Pool and merge statistics files.
8. Create final statistics.
9. Classify.
10. Print-out classification.
11. Use photo's and field experience to verify the classification.
12. If necessary, re-train to clean up classification.

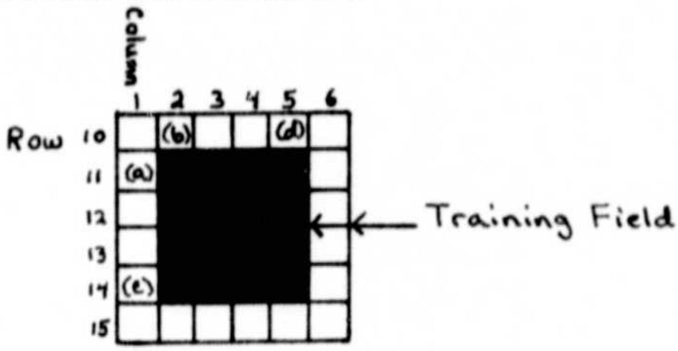
EDITOR COMMANDS

NOTE: Operator Commands in CAPITAL letters and underlined.

STEP

2) Record Row/Col coordinates:

(a) (b) (c) (d)
N, W, S, E
11, 2, 14, 5



3) Clip a Window:

!SUB
Input Window File= WIN.WOODSIDE
(Old Version)
2!COORDINATES
*NORTH, WEST, SOUTH, EAST CR
* " " " " "
* (same for each window of that resource type)
* CR(twice)
2! WRITE -(this writes the file and you must name it)
2!QUIT -(repeat steps for each resource type)

4) Print a Window:

!PRINT
Which output Device? T = (terminal)
Input window file= THE RESOURCE WINDOW YOU CLIPPED
See the list of window Y = (yes)
Which window displayed (-1 = all) -1
Which channel (1 thru 4) 2 (and the next run 4)
Global or local Histogram G
Display Histogram (Y,N or only) ONLY

5) Cluster a Window:

!RAW
2!CLUSTER
3!MODIFY
Disk File Name = ENTER YOU TRAINING WINDOW NAME
4!NUMBER OF CATEGORIES
Number of Clusters =WHATEVER YOU CHOOSE
4!DELTA OR SEPARABILITY THRESHOLD
Delta =.5
4!QUIT
3!ORDINARY CLUSTER
Use an imput statistics file (Y OR N) ? N
Input window file =THE NAME YOU ENTERED ABOVE
Minimum number of categories after merging (1 to ?)

STEP

5) con't

ENTER ONE LESS THAN YOU ASKED FOR ABOVE
What percent convergence? (0.00 - 100.0) 100
Enter maximum number of iterations to be performed
AT LEAST 15, GIVE THE COMPUTER A CHANCE
Want to see statistics? (Y or N) Y
Do you wish to save? (Y or N) Y IF IT IS GOOD
Output statistics file =NAME IT
Create a categorized window file? (Y or N) N
(repeat for each resource category)

7) Pool and Merge Stats:

!RAW
2!STAT file editing
Input Stat file= ENTER YOUR 1ST STATE FILE
#WRITE
Low cat, High cat = 1 space? WHATEVER NUMBER OF CLUSTERS YOU HAVE
#OPEN
Input Stat file= ENTER YOU NEXT STAT FILE
#WRITE
Low and high cat = REPEAT FOR THIS FILE
#GENERATE
Output Stat file= GIVE THESE TWO WINDOWS A NEW NAME
Do you wish to continue? (Y or N) Y
Input Stat file= ENTER THE SAME AS ABOVE
#SEPARABILITY SWAIN FU
Mark a threshold? (Y or N) Y
Threshold Value= .45
#VARIANCE
#MEANS
#NUMBER OF CLUSTERS
#WRITE (Whatever categories you want to save in order)
#POOL (Whatever categories you want to save in order)
***(Repeat until you have written and pooled all of the categories)
#GENERATE
Output Stat file=NAME THE FILE
(repeat for the next Stat file)
#OPEN
Input Stat file = PUT THE NAME OF THE FILE YOU JUST CREATED
#WRITE
(Continue on in this manner)
#QUIT (You have just created a final statistics file.)

STEP

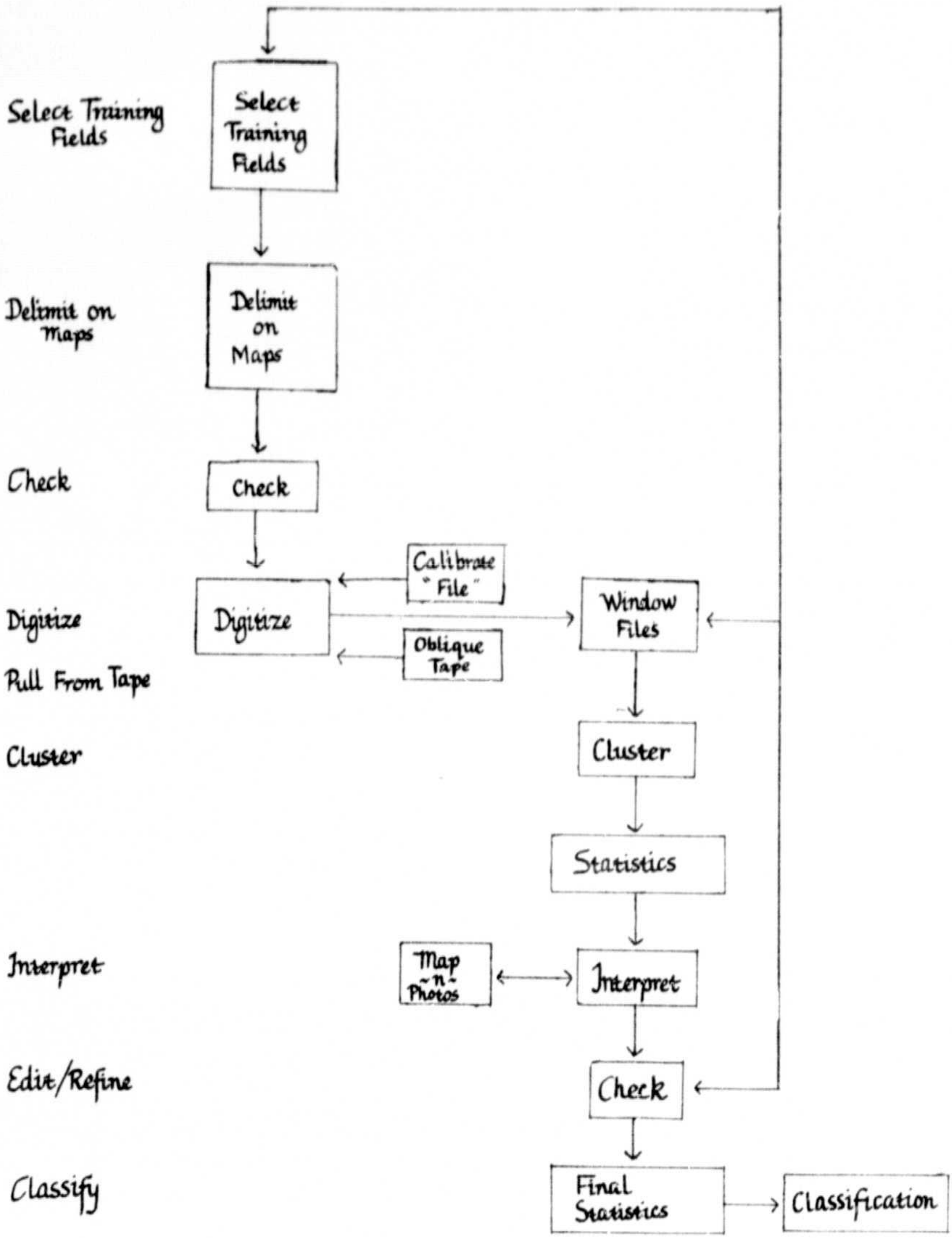
9) Classify:

```
!RAW
2!CLASSIFY
 Number of Channels= 4
3! GAUSSIAN
 Enter R for restart CR
 Enter increment to save CR
 Input Stat file = ENTER FINAL STAT FILE
 Input Window file = ENTER THE NAME OF THE WINDOW YOU
      WANT TO CLASSIFY
 Enter increment to Print CR
Cat Window file = NAME IT.  THIS WILL BE THE NAME OF
      YOUR CLASSIFIED WINDOW
2!QUIT
```

10) Print Classified Window:

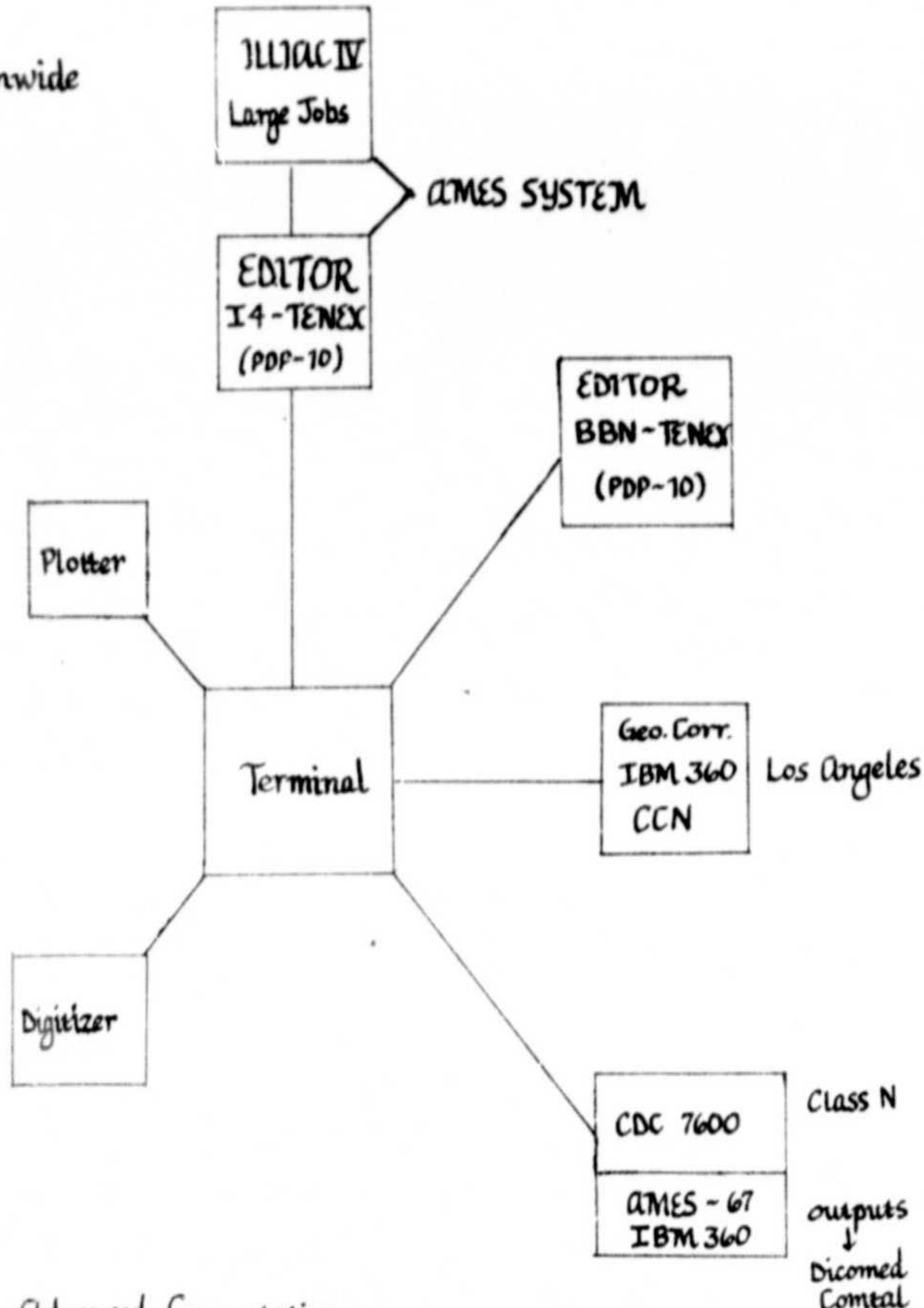
```
!PRINT
Which Output device?  T
Input window file= CAT."SOMETHING"
2!QUIT
```

DIGITAL DATA ANALYSIS



EDITOR SYSTEM

- Right computer for the right job
- Low equipment investment
- Simple to operate
- Accessible by phone nationwide



Developed by: Center for Advanced Computation, University of Illinos

Funded by: NASA, USDA, USGS, & ARPA.

APPENDIX 2

TECHNICAL PLAN

LANDSAT DEMONSTRATION PROJECT

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LANDSAT DEMONSTRATION

NSG - 2341

McCLOUD RANGER DISTRICT PROJECT

SHASTA NATIONAL FOREST

TECHNICAL PLAN

FINAL VERSION

Submitted By: Lawrence Fox III
Joseph Webster
Kenneth Mayer

PROPOSED: 7-10-78
REVISED: 11-14-78
FINAL: 2-25-79

OBJECTIVES

To:

1. Delineate Landsat forest cover categories for all forested land. These categories to correlate with U.S. Forest Service compartment analysis stratification.

2. Landsat will also define several spectral categories associated with general land use and land condition. Land use labels to be compatible with U.S. Forest Service requirements as far as possible.

3. Develop tabular summaries, by compartment, of acreages of all categories defined by Landsat.

4. Derive point estimates of number of trees/acre, basal area/acre, volume/acre Scribner and volume/acre cubic feet using Forest Service ground plot data and Landsat classification for a selected number of compartments within the District.

Introduction

National Forest managers are required to develop plans to harvest raw materials for the productive use of the forests. In addition, they are required to plan for the multiple use of forest resources. Managers must protect the forest for future generations by maintaining a sustained yield of products and services.

Under these stringent requirements, resource use decisions must be based on valid environmental data. Conventional ground data/air photo inventory methods provide data of sufficient accuracy, but not within the time frame needed for wise long-range planning of forest management alternatives. The information derived from Landsat in this project will be used in place of information now coming from conventional color aerial photography. The data produced will be used in forest type and land use classification. The data in each Landsat spectral category will be summarized by each compartment (a management unit) within the ranger district. This data will aid in the selection of resource management opportunities and therefore enable managers to rationally choose among management options in line with mandated activities and environmental constraints.

STUDY AREA

The Forest Service would like to study the McCloud Ranger District using Landsat, as a one year demonstration project. The project will focus on compiling and analizing data for each compartment (a management unit) within the District. The geographical location and area of the demonstration is as follows:

	Area	Location (lat - lon)
McCloud Ranger District	422,300 Ac.	N 40° 52.5' to 41° 37.5'
		W 121° 30' to 122° 22.5'

COOPERATORS

Listing:

1. U.S. Forest Service
   McCloud Ranger District
   P.O. Drawer I
   McCloud, CA 96057
   (916) 964-2184

2. Landsat Demonstration Project (NSG-2341)
   Humboldt State University
   Arcata, CA 95521
   (707) 826-4874

3. NASA Ames Research Center
   Mail-Stop 242-4
   Moffett Field, CA 94035
   (415) 965-5897

Coordination of Tasks:

The project will be a cooperative effort between the U.S. Forest Service, Humboldt State University, and NASA Ames Research Center. The Forest Service will provide personnel and funding to accomplish the Landsat classification. Humboldt State will provide all initial training and orientation to the Landsat perspective. Humboldt will provide follow-on training and consulting in digital processing. NASA will assist in digital analysis and consulting as needed due to some equipment limitations at Humboldt State. NASA will provide Landsat digital data, initial computer processing, registration, cosmetic clean-up, etc., and all final products required for the project.

Personnel-Duration and Level of Commitment:

U.S. Forest Service:

Project Leader - Don Campbell & Richard Gissibl	6 man-mos.	1 year
Forest Technician - Alice Forbes	120 days	1 year

Humboldt State University:

Principal Investigator - Lawrence Fox	1/2 time	1 year
Technical Assistant - Ken Mayer	1/2 time	1 year
Management Coordinator - Joseph Webster	1/4 time	1 year

NASA Ames Research Center:

Grant Monitor - Sue Norman	1/8 time	1 year
Technical Manager - Don Card	1/3 time	1 year

Overall Responsibilities:

NASA: Instruction in advanced analysis techniques, technical assistance, satellite data, other data as necessary, output products.

Humboldt State: Training, instruction, basic analysis techniques, technical assistance, consulting for project design and completion.

Forest Service: Actual Landsat digital analysis, digitizing, accumulation of ground data, evaluation and verification of final report.

OPERATIONAL PROGRAM

Program Objective:

Landsat Forest Cover and Land Condition map by Compartment (USFS management unit)

A. Test Area: Compartments (management units) within McCloud Ranger District-Shasta National Forest.

B. General Class Detail: Forest Cover and Land condition identifiable by Landsat, correlated with existing Forest Service requirements.

C. Scale: 1:100,000 for the entire district, 1:24,000 for selected 7½ quad maps.

D. Product: Color-coded map with compartment boundaries.

E. Summaries: Acreage summaries per Landsat category of the Ranger District. Estimates of the no. of trees, basal area, and volume per acre per category by selected compartments.

F. Landsat Data: August 29, 1976 (initial classification), August 1, 1978 (final product generation).

Data Needs:

NASA:

1. Landsat Data:

   Date: August 29, 1976 (initial classification)
   August 01, 1978

   Scene#: 5498-17305 (Aug. 29, 1976)

   Scene#: 30149-18111(Aug. 1, 1978)

2. Black & white enlargement of scene in #1 (Aug. 29, 1976) @ 1:500,000 (or larger).

3. Photography: Color IR of McCloud district - Aug. 2, 1978. (U-2)
   Natural color of McCloud district - Aug. 2, 1978. (U-2)

4. Line printer output as required for analysis.

Forest Service:

1. Provide map bases - 1:24,000 or available base. (Mylar)
2. Cluster/plot volume estimates on completed compartments.
3. All ground data collected on compartments and district, including geographical location of all cluster plots.
4. U-2 optical bar photography - Aug/Sept. 1978.

Program Approach:

The project will approach the processing of Landsat data for the McCloud Ranger District in two phases. The first phase will identify vegetation and land use/condition data for two selected compartments with similar forest cover. Statistics will be developed using the portable terminal available at HSU for each category identified by Landsat. These files will be used to classify the Landsat data for the two compartments.

Phase two will expand the initial classification statistics files for the remaining compartments. New statistics files will be developed for: 1.) New categories encountered, 2.) geographical variation in spectral signature, and 3.) Spectral variation within existing classes. Signature extension will be used when possible in new compartments of similar com-

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position. In this way each statistics file for each category classified will be added until all spectral signatures can be assigned to a category.

Phase I Analysis:

Two compartments, with similar forest cover will be selected for initial analysis. The Forest Service (FS) will provide map bases that identify the geographical location of these compartments within the District. The FS will supply all available cluster plot locations and volume estimates for these pilot areas.

The FS technician will begin transferring current stand type information from photos (USFS) to cebiachrome 7½ minute quad sheets. These polygons will be used as training fields for initial classification. Training fields for resource types not found on photos but known to exist in the District will also be delineated.

This information will be digitized into the Landsat data matrix to develop training statistics files for the final classification.

Responsibilities:

1. Choose two compartments for preliminary training/classification- USFS/HSU.
2. Create a Raw Data Window, August 29, 1976, Landsat scene and produce line printer maps of bands 5 (2) and 7 (4) NASA.
3. Develop an ILLIAC unsupervised classification of Raw Data Window NASA.
4. Provide black and white enlargement, at 1:250,000, of August 29, 1976 Landsat scene.
5. Transfer training field information to 7½ minute quads. USFS.
6. Develop calibration file for August, 1976 data. HSU/NASA.
7. Digitize training fields and compartments. HSU/NASA.
8. Editor processing to develop statistics files on training field. USFS/HSU.
9. Run a supervised classification on the two fields. USFS/HSU.
10. Extend supervised classification to compartments of similar composition. USFS/HSU.
11. Verify initial supervised classification. USFS/HSU.

Phase I Classification:

The following categories are expected within the pilot study areas. Each of these classes will be labeled and correlated as closely as possible to existing FS labels and sampling scheme.

Resource Category	Stocking Level [1]	Size Class [2]	Landsat Label'
PONDEROSA PINE	Good	Large Small	PGL PGS
	Poor	Large Small	PPL PPS
MIXED CONIFER	Good	Large Small	MGL MGS
Red fir White fir Insense Cedar Douglas fir Ponderosa pine Lodgepole pine Knobcone pine	Poor	Large Small	MPL MPS
LODGEPOLE PINE	Good	Large Small	LGL LGS
	Poor	Large Small	LPL LPS
RED FIR	Good	Large Small	RGL RGS
	Poor	Large Small	RPL RPS
PLANTATION (several stages of early succession)			PL
MARGINAL COMPONENT			M
Meadows Bare soil Lavas			
WATER			WA

[1] Good stocking is ≥ 40% crown closure
Poor stocking is < 40% crown closure

[2] Large trees are ≥ 24 ft. in crown diameter
Small trees are < 24 ft. in crown diameter

Phase II Analysis:

Phase II Analysis will repeat those steps outlined under Phase I. Additional statistical analysis for new resource category identification will be added until all spectral signatures have been classified.

Sampling Design:

The Landsat data will cover the entire Ranger District. The forest cover and land use inventory will be a 100 per cent inventory of the District with a sampling unit size of approximately one acre, a Landsat pixel.

Certain forest stand parameters(trees per acre, basal area per acre, and volume per acre) will be derived from existing Forest Service cluster plot data for each Landsat category. The cluster plots will be assigned to the particular Landsat category(or strata) they occur in. This design will assure a stratified cluster sampling design with random starts since the ground plot starting points have already been located by the Forest Service independently from any Landsat stratification. Statistical analysis will provide point estimates and 95% confidence intervals for all forest stand parameters.

The Forest Service will tally all ground plots occurring in each Landsat strata for the limited number of compartments chosen for this extended analysis. These plots will be submitted to the Humboldt State Project Office for all statistical calculations. Humboldt Personnel will work with the Forest Service to properly tabulate and document this step. NASA Personnel are requested to provide consulting for statistical procedures.

Evaluation Procedures:

The Landsat classification will be evaluated using a three stage cluster sample with random starts. 1:120,000, U-2 color, infrared and color photography will be used in conjunction with 1:15,840 Forest Service photography to provide a standard for evaluating Landsat accuracy. Point estimates for errors of omission and commission, with lower error bounds for omission at 95% confidence, will be specified. The accuracy will be evaluated on a pixel by pixel basis with each cluster used to estimate the proportion of correctly classified pixels.

PROPOSED SCHEDULE

TASKS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Initial Classification, Phase I, '76 data	----	----	----	----	*							
Obtain '78 Digital Data Tape	----	----	----	*								
Define Training Areas-Phase II			----	----	----	*						
Editor Processing					----	----	----	----	*			
Finalize Classification						----	----	*				
Generate Output Products								----	----	*		
Evaluate Landsat Classification							----	----	---- *			
Final Report Documentation									----	----	---- *	

OUTPUT PRODUCTS

1. (a) Three (3) color photo prints (32" x 32") of the final forest cover classification of the McCloud Ranger District, including compartment and ownership boundaries, at 1:100,000. Annotation to be added prior to development.

   (b) Three(3) color photo prints (32" x 32") of the final land use/condition classification of the McCloud Ranger District, including compartment and ownership boundaries, at 1:100,000. Annotation to be added prior to development.

2. Six photo prints(18" x 24" scaled to match 1:24,000 cebiachrome quad sheets) of the final Landsat forest cover classification with compartment and ownership boundaries for selected 7½ minute quads provided by the Forest Service (area of coverage to be selected by US Forest Service).

3. Fourteen 8" x 10" photo reproductions of each photo product in number "1" above.
   Fourteen 8" x 10" photo reproductions of one of the six prints in number two above.

4. Line printer maps (grey level maps for each Landsat Channel and unsupervised classification) of the McCloud Ranger District, three copies.

5. Statistical summary tables, acreage by class, for each compartment, three copies.

6. Master negatives for all photo products in 1 and 2 above.

7. 35 mm slides and overhead projector transparencies of photo products in 1 and 2 above.

TASK PLAN

PHASE I	COOPERATOR	ACTUAL COMPLETION DATE
1. Initial Field Orientation		
a. Review Forest Service sampling techniques.	HSU/USFS	10-16-78
b. Review existing Forest Service ground truth/photo information.	HSU/USFS	10-16-78
c. Selection of pilot study compartments.	HSU/USFS	10-17-78
d. Field inspection of forest cover, land use/condition of Ranger District -photos and field site inspection.	HSU/USFS	10-17-78
COOPERATORS: HSU, USFS PROPOSED COMPLETION DATE: 10-18-78		
2. Landsat Data Acquisition		
a. Obtain Landsat scene #5498 (1498)-17305 August 26, 1976 prepare geometric corrections and initial processing of computer tape.	NASA	10-15-78
b. Prepare ILLIAC IV unsupervised classification on window of McCloud District from scene #5498 (1498)-17305.	NASA	11-16-78
c. Prepare grey level map - bands 5(2) & 7(4) of McCloud window.	NASA	11-02-78
d. Obtain 5 black & white photo enlargements of scene # 5498 (1498)-17305 @ 1:250,000.	NASA	11-10-78
e. Place McCloud window on TENEX for EDITOR processing	NASA/HSU	11-16-78
f. Order Landsat scene (Aug, 1978)	NASA/HSU	11-17-78
COOPERATORS: NASA, HSU PROPOSED COMPLETION DATE: 11-18-78		

Task	COOPERATOR	ACTUAL COMPLETION DATE
3. Assemble Ground Truth Information		
a. Transfer cluster plot information from photos (FS) to 7½ min. cebiachrome quads and delineate training fields on 7½ min. quads.	USFS	11-13-78
b. Mark points on 1:250,000 Forest Service map for control point location.	USFS	11-13-78
c. Provide quad sheets with boundaries of compartments delineated.	USFS	11-06-78
d. Assemble 1975 photo coverage of pilot study compartments.	USFS	11-13-78
COOPERATORS: USFS PROPOSED COMPLETION DATE: 12-1-78		
4. Initial Computer Processing		
a. Locate control points on black & white photo enlargements and Forest Service maps at 1:250,000. Record longitude/latitude from maps for each point, determine latitude/longitude for control points on photo.	HSU/USFS	11-17-78
b. Assemble calibration file, check points for minimum pixel location accuracy.	HSU/USFS	11-16-78
c. Digitize compartment boundaries.	HSU/USFS	11-17-78
d. Create sub window file for each compartment, ARCHIVE McCloud window and hold sub windows on TENEX.	HSU/USFS	11-17-78
COOPERATORS: HSU, NASA (computer) PROPOSED COMPLETION DATE: 12-5-78		

	COOPERATOR	ACTUAL COMPLETION DATE
5. EDITOR Processing 1976 Scene		
a. Generate masks.	HSU/USFS	12-01-78
b. Pack segment files.	HSU/USFS	12-01-78
c. Cluster all resource types.	HSU/USFS	12-01-78
d. Merge and pool statistics.	HSU/USFS	12-01-78
e. Final statistics.	HSU/USFS	12-01-78
f. Unpack multi-window files and print classification of training fields with guided clustering statistics.	HSU/USFS	12-15-78
g. Run ILLIAC IV classification of McCloud window for scene #5498 (1498)-17305, August 26, 1976.	HSU/USFS/NASA	12-15-78
h. Compare classification to aerial photographs, refine as needed (iterate steps 5a - 5f as needed).	HSU/USFS	12-18-78

COOPERATORS: HSU, USFS, NASA (computer)
PROPOSED COMPLETION DATA: 12-20-78

PHASE II	COOPERATOR	ACTUAL COMPLETION DATE
1. Initial Computer Processing, 1978 Landsat Scene		
a. Delimit new training areas on 7½ min quads for the next 3 compartments.	USFS	2-23-79
b. Clip McCloud from gray map channel 2.	HSU/USFS	2-23-79
c. Create calibration file.	HSU/USFS/NASA	
d. Digitize training fields.	HSU/USFS	
e. Digitize compartment and district boundries.	HSU/USFS	

COOPERATORS: HSU, USFS, NASA (computer)
PROPOSED COMPLETION DATE: 3-1-79

	COOPERATOR	ACTUAL COMPLETION DATE
2. EDITOR Processing 1978 Scene (McCloud)		
a. Generate mask with old segments and new OCAL file and data.	HSU/USFS	
b. Cluster all fields (resource categories).	HSU/USFS	
c. Pool and merge statistics for '78 data.	HSH/USFS	
d. Pool and merge '78 stat. file with '76 statistics to see how similar the 2 years are.	HSU/USFS	
e. Run unsupervised classification for '78 data and merge statistics with supervised (guided clustering).	HSU/USFS	
f. Unpack multi-window files and classify the training areas.	HSU	
g. Print classified training areas.	HSU/NASA	
h. Run ILLIAC classification for '78 McCloud window.	HSU/NASA	
COOPERATORS: HSU, USFS, NASA (computer) PROPOSED COMPLETION DATA: 3-16-79		
3. Evaluation		
a. Color classes on the LP classification and identify resource categories.	USFS	
b. Examine overall accuracy and identify misclassified areas.	HSU/USFS	
c. Retrain on areas with spectral confusion.	HSU/USFS	
d. Enter any resource categories that may have been missed into the '78 statistics file.	HSU/USFS	
COOPERATORS: HSU, USFS PROPOSED COMPLETION DATE: 5-01-79		

	COOPERATOR	ACTUAL COMPLETION DATE
4. Derive Forest Stand Parameters for Landsat Cover Categories		
a. Digitize cluster plot centers for selected compartments.	HSU/USFS	
b. Calculate stand parameters by Landsat forest cover class, point estimates and confidence intervals.	HSU/USFS	

COOPERATORS: HSU/USFS
PROPOSED COMPLETION DATE: 7-15-79

APPENDIX 3

COST SUMMARY

US FISH AND WILDLIFE SERVICE and HSU/McINTIRE-STENNIS

LANDSAT DEMONSTRATION PROJECT

(Actual Project completed under
NSG-2244, Cost Summary completed
under current grant NSG-2341)

TABLE I

	COST		
SOURCE OF FUNDS	TOTAL PROGRAM	USFWS PROJECT	HSU McINTIRE-STENNIS
NASA	$16,500.00	$ 8,250.00	$ 8,250.00
HSU/NSG-2244	21,408.00	10,704.00	10,704.00
HSU/McINTIRE-STENNIS	5,200.00	-0-	5,200.00
US FISH & WILDLIFE SER.	3,900.00	3,900.00	-0-
TOTALS	$47,008.00	$22,854.00	$24,154.00
COST PER ACRE			
139,500 a. HOOPA SQUARE, KLAMATH STRIP	.337*	.164	-0-
83,975 a. HOOPA SQUARE	.560	-0-	.288
223,475 a. HOOPA SQUARE, KLAMATH STRIP BOTH PROGRAMS	.210		

*dollars per acre

40

APPENDIX 4

STATEMENT OF ACCURACY

US FISH AND WILDLIFE SERVICE

LANDSAT DEMONSTRATION PROJECT

(Actual Project completed under NSG-2244, Accuracy Evaluation completed under current grant NSG-2341)

Table 4. Error of Omission

Category	Mean Probability of Correct Classification	Standard Deviation	Cluster Sample Size (# of clusters)	Lower Limit 95% Confidence Level
>80% CC[a] Brush	0.910	0.040	15	-0.070 (0.84)
Conifer	0.973	0.012	15	-0.021 (0.95)
Mixed	0.883	0.022	18	-0.038 (0.85)
Hardwoods	0.880	0.038	14	-0.076 (0.81)
60% CC "	0.850	0.055	17	-0.096 (0.75)
50% CC "	0.951	0.032	23	-0.055 (0.90)
40% CC "	0.971	0.025	9	-0.046 (0.93)
30% CC "	0.810	0.146	7	-0.276 (0.54)
20% CC "	0.956	0.027	17	-0.047 (0.91)
<10% CC "	0.933	0.024	18	-0.041 (0.89)
Water	0.863	0.08	6	-0.165 (0.70)
Overall	0.916	0.0089	36	-0.015 (0.90)

[a]CC = Crown Closure

Table 5. Error of Commission

Category	Mean Probability of Correct Classification	Cluster Sample Size (# of clusters)
Conifer	0.976	15
Mixed	0.974	18
Hardwoods	0.914	7
>80% CC[a] Brush	0.670	15
60% CC "	0.884	8
50% CC "	0.858	20
40% CC "	0.971	9
30% CC "	0.884	8
20% CC "	0.913	11
<10% CC "	0.804	11
Water	0.833	4
Overall	0.914	30

[a]CC = Crown Closure